Inertial Pen Based Alphabet Recognition using KNN Classifier

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Abstract— In today's electronics world human machine interface is important part. Pen with inbuilt inertial sensors devices capture human handwriting or drawing motions in real-time and use the sensor data for recognition. An inertial sensor based Inertial pen consist of an inertial sensor MPU 9150(accelerometer gyroscope and magnetometer), microcontroller, and a wireless transmission module, for sensing and collecting movement data for writing alphabet. The sensor data is received and processed for alphabets, recognition. The recognition algorithm composes of the steps of sensor data acquisition, signal pre-processing, feature generation, feature selection, and classification. KNN Classifiers for classification among 26 capital alphabets classes is built. The project aims at to validate the effectiveness of the inertial pen based motion data acquisition and recognition of class of test sample from among 26 classes. The recognition accuracy achieved is 82%. The recognition accuracy of 93 % is achieved for recognition of four gestures.

Keywords— inertial   Pen, KNN classifiers, MPU9150, alphabet recognition, feature generation, Statistical features, Confusing classes.

INTRODUCTION

Touchscreen and keyboard are the most commonly used devices for alphanumeric entry. As the size of the electronics gadget is reducing, size of the keypad is also becoming small. Touchscreen entry of alphanumeric character is tedious as the size of the alphabet/number on the touchscreen is less than the tip of the finger, so requires very attentive and precise handling. Also text entry using keys which has size smaller than fingertip is time consuming and requires great attention for accuracy. So text entry by touchscreen or keyboard using for continuously reducing electronic gadget is tedious. As an effective alternative for text entry researchers have focused on inertial sensor based human machine text interface.
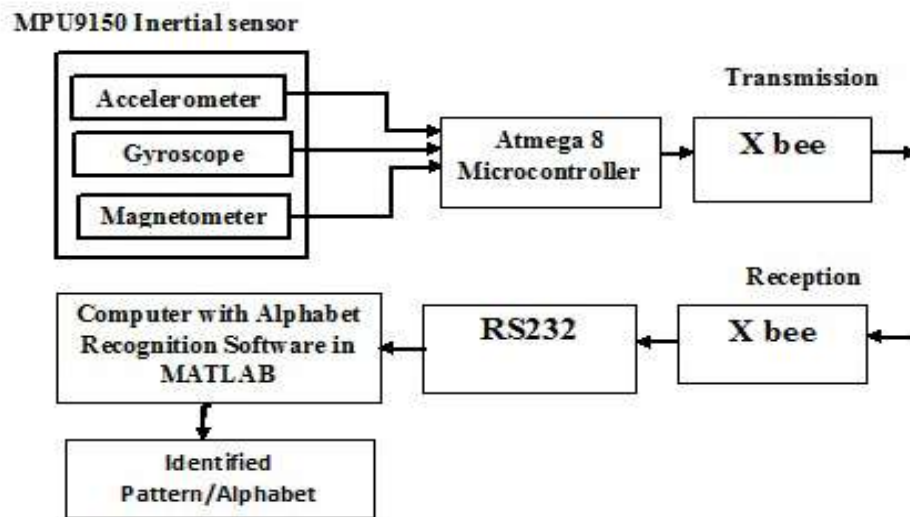

Figure 2: Block diagram of alphabet recognition system

RELATED WORK

 More work is done for human machine interface using gestures. Machine is trained to recognize few gestures which are used to give command i.e. to control the machine. Accuracy obtained in gesture recognition (up to 7 gestures) is 99.99% by using one inertial sensor accelerometer and pattern recognition techniques.

Different types of input or sensing devices were used by researchers. Body-worn sensors, camera, combination of head mounted camera and accelerometers worn at the wrist [2], data glove [1], hand held pen like device equipped with inertial sensors. Different combinations of the inertial sensors were used. Single triaxial accelerometer [3], two dual-axis accelerometers mounted on pen [4], combination of accelerometer and gyroscope inbuilt with smartphone [5], accelerometer gyroscope and magnetometer [6]. Inertial sensor based input devices gives the convenience like writing with pen, as size of inertial sensor with processing is reduced to few tens of millimeter.

The motion data obtained from inertial signal is processed for recognition using pattern recognition or classifier technics. The most successful techniques for pattern recognition are dynamic time wrapping and trajectory recognition algorithm. For online digit recognition [7], digits written with accelerometer based pen are recognized using dynamic time wrapping algorithm. In this after pre-processing of the sensor signal the test signal sequence in time domain is directly compared with reliable training template of each class. Euclidean distance of each class template and test sequence was calculated, then the pattern with the minimum distance is selected as the class of test sequence. User dependent recognition rate obtained was 90.6% and user independent recognition obtained was 84%. Digit (0-9) and eight hand gesture recognition [3] using trajectory recognition algorithm gave good recognition rate of 98% and 98.75% respectively. Trajectory recognition algorithm consists of signal preprocessing, feature generation, feature selection (with

KBCS (kernel-based class separability) and LDA (linear discriminate analysis)) and PNN classifier.

In majority of research work on character or gesture recognition classification among less number (maximum 10) of classes was carried out.

In this paper recognition of 26 capital letter is implemented using inertial pen with 9 degree of freedom and KNN classifier. The hand movement and hence the inertial sensor data for writing letters like 'D' and 'P' or 'C' and 'U' has a great similarity. So it is challenging to implement the character recognition for 26 alphabets which consists of many such confusing classes. Hence to improve recognition rate KNN classifier is used on large feature dimension vector (9X6=54).

Character Recognition System

In this project, we have designed an inertial signal acquisition device called inertial Pen." This inertial pen consists of a tri-axial accelerometer a tri-axial gyroscope, a tri-axial magnetometer and microcontroller. The microcontroller is connected to computer via RF transmitter.

The major components of the hardware implemented includes, the MPU-9150 as inertial sensor, ATmega8 a low-power CMOS 8-bit microcontroller and X-bee. In MPU9150 multiple sensors are integrated into one small package. It h combine an accelerometer/gyro with a Hall-sensor magnetometer and a Digital Motion Processor (DMP) hardware accelerator engine into one 4 mm x 4 mm package. It is the smallest 9-axis freedom sensor.

The MPU-9150 has three 16-bit analog-to-digital converters (ADCs) for digitizing the gyroscope outputs, three 16-bit ADCs for digitizing the accelerometer outputs and three 13-bit ADCs for digitizing the magnetometer outputs. The MPU-9150 communicates to the system processor i.e. ATmega8 microcontroller using an I^2C serial interface which operates at 400 kHz.
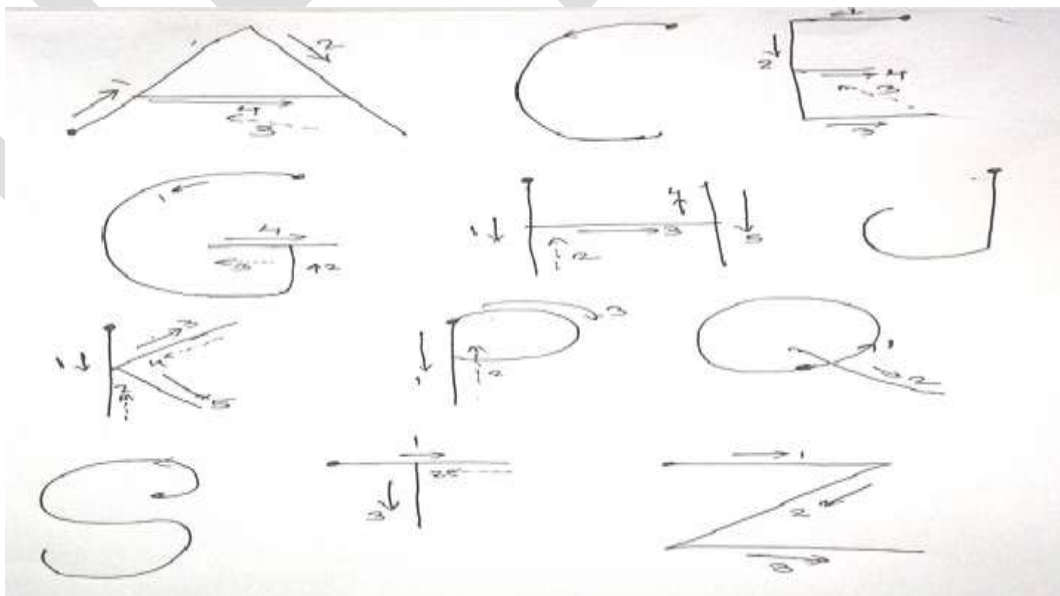

Figure 3: The trajectories of few alphabets

When the user draws some pattern on the paper or makes some gestures in 3-D space by using the Inertial pen, the inertial pen acquires the inertial signals produced. The accelerometer, gyroscope, and magnetometer are used to detect accelerations, angular velocities, and magnetic signals generated by hand movements. The microcontroller collects the digital accelerations, angular velocities, and magnetic signals, and transmits the inertial signals for further signal processing and analysis.
The trajectories of few alphabets is shown in the figure [2].

This transmitted data is nothing but the X, Y and Z directional acceleration, angular and positional data. Thus, there is a set of 9 values transmitted by the inertial pen hardware to the PC at every instant.

Flow of software development is as shown in fig [3]. A signal processing and software system built using MATLAB R2013a.
Software developed can be divided into following parts
   1) Preparing database for both training and testing stages.
   2) Training stage.
   3) Testing stage both offline and real time.
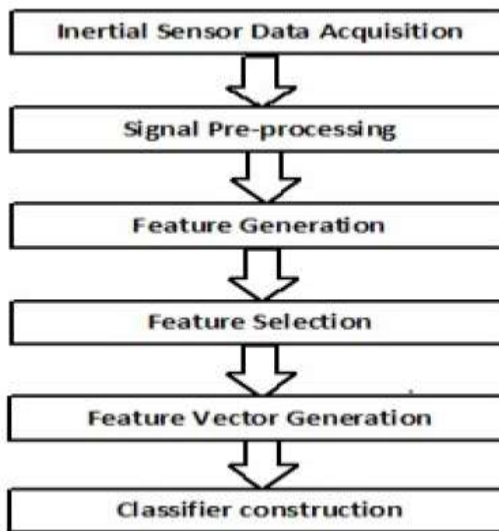
Figure 4: Flow of Software Development

Software development start with inertial signal acquisition for training stage, which is used to prepare database. The database of 26 Capital alphabet is prepared. Each letter is written 10 times so there are 10 samples of each alphabet. So 26X 10 =260 samples are obtained. The data from sensor is transmitted and received by using X bee .The data from serial port is read and saved in a text files. To prevent the movement data other than the movement of inertial pen for writing letter, the inertial pen is held in a constant reference position(vertical)for certain time say 5 seconds before starting to write the letter. A letter is written in fixed time frame of 25 sec. If letter is written in less than 25 sec again the pen is held in reference position for rest of the time within 25 sec. The next step is to generate the feature vector template of all classes. It includes reprocessing of signal and feature generation. The preprocessing of the signal   is done to reduce the amount of data to be processed. It is done by filtering, and confining the data values within a range (normalization to remove an outlier i.e. An extreme value that differs greatly from other values.) . The processed and unprocessed inertial sensor signal is as shown in figure [4] .Then the following statistical features are extracted.
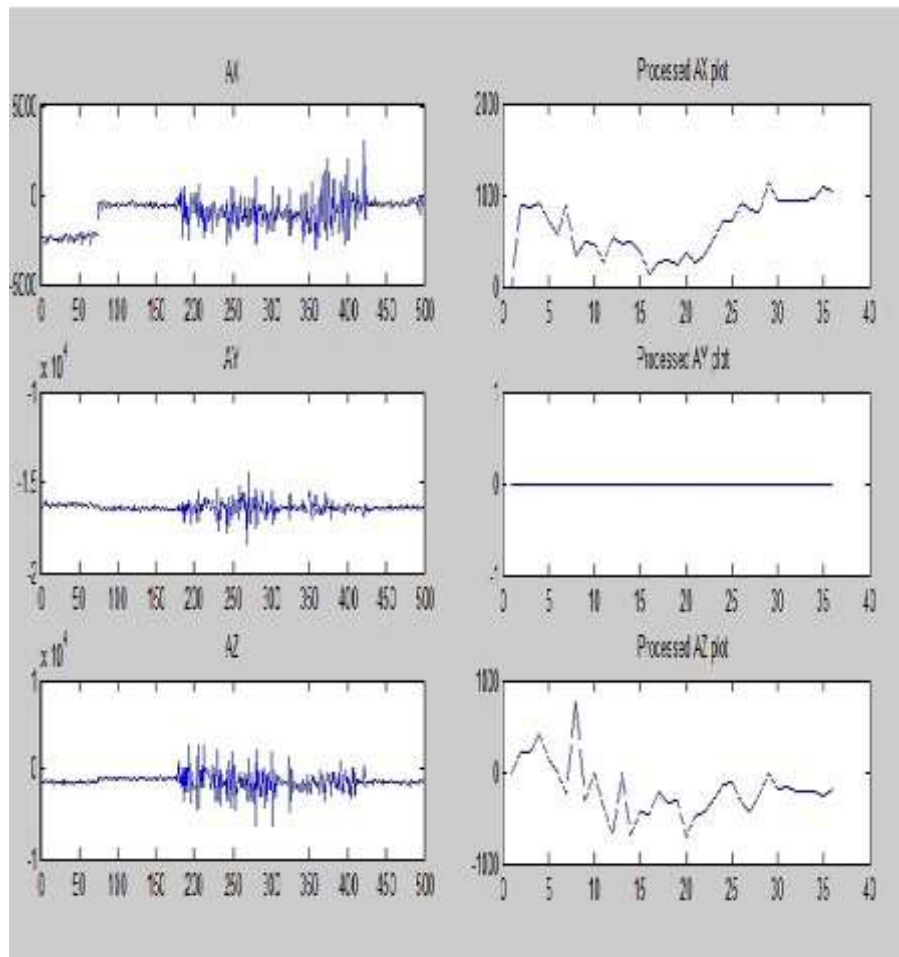
Figure 4: unprocessed and preprocessed accelerometer signal of letter 'L'

Statistical features describe the amount of variability or spread in a set of data. The most common measures of variability are the range, the interquartile range (IQR), variance, and standard deviation .The features generated are Mean, Variance, Mean absolute deviation, standard deviation, interquartile range, range, number of zero crossing and RMS. A feature vector containing the values of these features for each letter is formed and stored in a array as template classes.

During testing stage the processes of test signal acquisition pre-processing and feature vector generation is similar to training stage. The feature vector of test signal and feature vector array of all classes are passed to classifier function for recognition. Since the recognition is be achieved from among comparatively large number (26) of confusing classes KNN classifier is used.

The implemented system is tested using five sets of test sample, i.e. each letter is written five times. Each time the result is recorded. The results obtained are given in Table [1].

$$\text{Percentage Recognition} = \frac{R \times 100}{130}$$

$$R = 107$$

$$\text{Percentage Recognition} = \frac{107 \times 100}{130}$$

$$= 82\%$$

The same system when used for recognition of four gesture gave 93 % recognition rate.
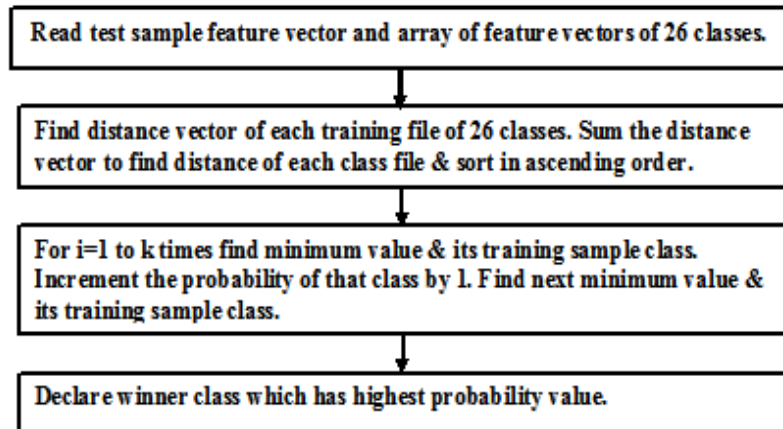
Read test sample feature vector and array of feature vectors of 26 classes.

Find distance vector of each training file of 26 classes. Sum the distance vector to find distance of each class file & sort in ascending order.

For i=1 to k times find minimum value & its training sample class. Increment the probability of that class by 1. Find next minimum value & its training sample class.

Declare winner class which has highest probability value.

Figure 5: Implementation of KNN classifier

Table 15: Recognition table for 5 test samples

Alphabet	Test Sample 1	Test Sample 2	Test Sample 3	Test Sample 4	Test Sample 5	NO.Of Correct Recognition
A	✓	✓	✓	E	F	3
B	U	X	✓	✓	✓	3
C	U	U	✓	✓	✓	3
D	✓	✓	✓	✓	✓	5
E	✓	D	✓	✓	✓	4
F	✓	✓	✓	✓	G	4
G	✓	✓	✓	✓	✓	5
H	✓	✓	✓	✓	✓	5
I	✓	✓	✓	✓	✓	5
J	✓	✓	✓	✓	✓	5
K	✓	✓	✓	✓	✓	5
L	✓	✓	J	J	✓	3
M	✓	✓	J	J	✓	3
N	✓	✓	✓	H	✓	4
O	✓	✓	✓	✓	✓	5
P	✓	D	✓	D	✓	3
Q	✓	✓	✓	✓	A	4
R	✓	H	✓	✓	✓	4
S	✓	✓	✓	✓	✓	5
T	✓	✓	E	✓	✓	4
U	✓	✓	✓	✓	✓	5
V	W	✓	✓	M	✓	3
W	H	✓	✓	✓	✓	4
X	✓	✓	B	✓	✓	4
Y	✓	P	✓	✓	✓	4
Z	✓	✓	✓	✓	✓	5
Total no of correct recognition out of 130(26×5)						107

Conclusion:

I implemented inertial pen which consists of sensor MPU 9150 to collect motion data while writing alphabets. The sensor is selected as it consists of accelerometer, gyroscope and magnetometer and is of very small in size. Alphabet recognition is very challenging as there is great similarity between various characters, contains angular movements, straight line movement and also number of characters to be recognized are also large(classification in 26 classes). After signal preprocessing 8 statistical features are extracted. Alphabet recognition is accomplished in two stages, First is training stage and second is testing stage. Each of 26 alphabet is written 10 times i.e.it gives 10 samples for each letter. Out of 10 samples for of each alphabet 5 samples are used as training samples. Remaining 10 samples are used for testing. During training stage, feature vector is generated for each of 5 training samples of 26 alphabets is generated. Recognition accuracy is calculated for two classifiers, Simple PNN classifiers and KNN classifiers. KNN classifier gave better recognition accuracy (82%) for 26 characters. Recognition accuracy highly depends upon,

1. Consistency in writing style and speed
2. No of training samples.

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